Near-Surface Physical Field Characterization Methods for Conservation Personnel

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Table 1. Quality class placements for infiltration based on comparison of measured values to near-surface interpretive Ksat (permeability).[a/]

Measured	Estimated						
in hr^{-1}	6 - 20	2 - 6	0.6 - 2	0.2 - 0.6 in hr^{-1}	0.06 - 0.2	0.01 - 0.06	< 0.01
6 - 20	4	2	2	3	3	--	--
2 - 6	4	4	5	5	5	5	5
0.6 - 2	3	4	4	5	5	5	5
0.2 - 0.6	2	3	3	4	4	5	4
0.06 - 0.2	1	2	2	2	4	4	4
0.01 - 0.06	1	1	2	1	2	4	3
< 0.01	1	1	1	1	1	2	--

[a/] The minimum interpretive Ksat class within 60 cm for the short-term and 40 cm for the long-term is used. For the short-term infiltration, the measured value is divided by 2. For the long term, the measured value is used. The > 20 and < 0.06 in hr^{-1} classes are not included.

Table 2. Bulk density quality class placements as related to percentages of 2 - 0.1 mm and clay.

	Bulk Density			
Class	Sand > 0.1	Clay 15 - 25 g cc[-1]	Clay 25 - 35 g cc[-1]	Clay 35 - 60 g cc[-1]
5	< 10	< 1.15	< 1.10	< 1.05
4		1.15 - 1.25	1.10 - 1.20	1.05 - 1.15
3		1.25 - 1.45	1.20 - 1.40	1.15 - 1.35
2		1.45 - 1.60	1.40 - 1.55	1.35 - 1.50
1		≥ 1.60	≥ 1.55	≥ 1.50
5	25 - 50	< 1.25	< 1.20	< 1.15
4		1.25 - 1.35	1.20 - 1.30	1.15 - 1.25
3		1.35 - 1.55	1.30 - 1.50	1.25 - 1.45
2		1.55 - 1.70	1.50 - 1.60	1.45 - 1.60
1		≥ 1.70	≥ 1.65	≥ 1.60

Sand 10 - 25 and ≥ 50% excluded. Also, clay < 15 and ≥ 60%.

**Table 3. Classes of quality for penetration resistance and Singleton Blade Strength.**

Index	Penetration Resistance MPa	Singleton Blade Strength [a/] kg dm^{-2}
5	< 0.5	≥ 16
4	0.5 - 1.0	8 - 16
3	1.0 - 1.5	4 - 8
2	1.5 - 2.0	2 - 4
1	≥ 2.0	< 2

[a/] For water erosion. Classes may be different for other applications.

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Introduction

The objective is to present simple methods for in-place physical characterization of the near-surface that pertain to soil quality evaluation and are reasonably rigorous. Measurements include infiltration rate, maximum penetration resistance and bulk density (0-20 cm), shallow strength by the Singleton Blade method, and morphology (0-30 cm). Indexing protocols are given for all measurements. Antecedent water-state is brought to the 10-100 mb (very moist) range by wetting the previous day. All measurements can be done by NRCS field office staff except for morphology.

Methods
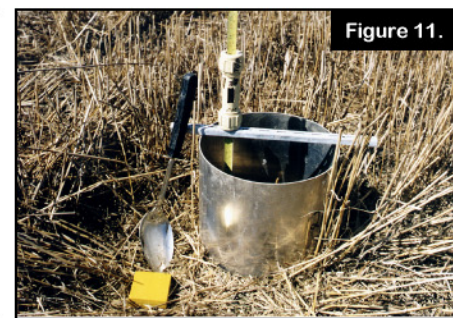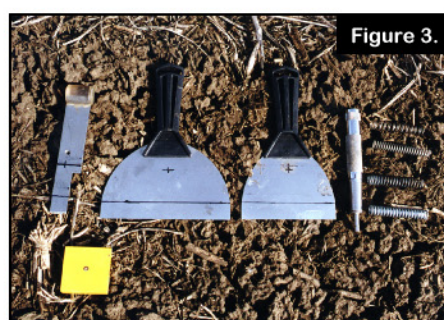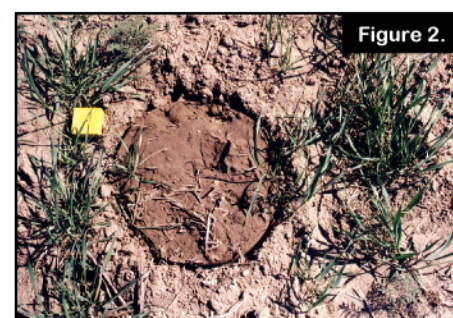
(Day 1) Step 1 - Figures 1-2. Insert 5 rings (30-cm diameter and 15-20 cm high). Three are inserted into the zone of compaction or to at least 10 cm and two to 5 cm. Two rings (to be removed after wetting) are inserted shallower to reduce disturbance on removal. Four rings suffice if Singleton Blade strength is not measured, while three rings are used if only infiltration is measured.

Step 2 - Place 3 to 10 cm of water in the rings. The amount of water depends on texture and water state. The objective is to wet to 30 cm. Consider using distilled water brought to 0.01M CaCl2. If very moist or wet, it may be unnecessary to wet.

(Day 2) Step 3 (Optional) - Figures 3-4. Remove a shallowly placed 30-cm ring. Wet with 2.5 cm of water for 5 minutes. Allow to drain until glistening has nearly but not completely disappeared. Determine the Singleton Blade strength 0-1, 0-2, and 4-6 cm with 0-1 cm optional. Apply force necessary to rotate 45° with pocket penetrometer 6 cm from blade edge. Report strength in kg dm^{-2}.

Step 4 - Remove another shallow ring. Obtain a soil slice to 30 cm from the wetted volume. Determine the morphological index, which is based on structure, moist rupture resistance, and surface-connected macropores.

Step 5 - With a pocket penetrometer, determine the depth of highest penetration resistance within 20-cm depth for the vertical wall exposed in Step 4.

Step 6 - Insert 15-cm diameter rings in the middle of the 30 cm rings to at or below the depth of highest penetration resistance within 20 cm (Step 5).

Step 7 - Figures 5-6. Line the 15-cm rings with plastic. Place 5 cm of water in the rings using a 1000-cm graduate cylinder. Remove the plastic to initiate infiltration. After 5 minutes, remove the water remaining. First, use a suction gun or a rotating pump attached to a drill. Follow with a 60-cc syringe. Let drain or blot until all of the free water has disappeared but glistening is still present, although considerably reduced in expression from the initial. Place 5 cm of water back in the rings. Infiltrate a second time for 5 minutes. Remove the water remaining in as near to 5 minutes as possible and measure the volume with a 1000-ml graduate cylinder. Calculate the infiltration rate for the 5-minute period ("short-term").

Step 8 - Immediately add a third 5-cm of water and continue infiltration for two to four hours or until one-fourth of the ground surface is exposed, whichever is first. Calculate the infiltration rate ("long-term").

Step 9 - Figure 7. Measure maximum penetration resistance 0-20 cm either on a vertical or horizontal face. If the former, also measure bulk density for the vertical face.

Step 10 - Figures 8-11. Determine bulk density either on a vertical or horizontal plane at the depth of maximum penetration resistance. For the former, a ring (5-cm diameter) or a short probe may be inserted. Use of 10-cm rings vertically has the disadvantage that the sample may not accord well with the depth of maximum penetration resistance. If the sample comes from a horizontal plane and will remain in the core, 10-cm rings are inserted 2-3 cm. In-place volume is determined from the product of the core area and the difference in distance between the ring empty and partly-filled. If soil does not remain in the core when the ring is removed, a 20-cm diameter ring is pushed into the soil a short distance. Distance from the soil to a reference level is measured. Excavation follows. Distance is measured again. From the change in distance and the core area the in-place volume of the soil removed is measured. Horizontal insertion has the advantage that the thickness is less. The zone of highest penetration resistance can be more closely sampled because the depths of the bulk density and penetration resistance measurements are very similar.

Figure 1.

Figure 2.

Figure 3.

Figure 4.

Figure 5.

Figure 6.

Figure 7.

Figure 8.

Figure 9.

Figure 10.

Figure 11.

Quality Classes

Each measured property is placed in a class from 1 to 5 (with 5 the best). The class sets follow:

Infiltration: In Table 1, the estimated near-surface Ksat (generally referred to as "permeability") is compared against the measured infiltration. It is assumed that the estimated Ksat is for grassland or woodland and not cropland.

Maximum Bulk Density: Table 2 gives the classes. It is assumed that bulk density increases as sand 0.1-2 mm rises and decreases as clay rises.

Maximum Penetration Resistance: Table 3 gives the ranges for the classes.

Singleton Blade Strength: Table 3 contains the classes. The mean for 0-2 and 4-6 cm is used.

Figure 12.

Morphology Index: Table 4 gives classes for the 0-30 cm based on structure, rupture resistance, and surface-connected macropores. All are for field capacity or wetter. Structure is given more weight than rupture resistance for medium and fine layers while rupture resistance alone is used for coarse layers. Macropores override if their index is higher than structure/rupture resistance. Raindrop impact crust is also considered in calculation of the index. Dry rupture resistance and thickness of the reconstituted zone of the crust determine the class. Class definitions are not provided here. Values weighted by depth are calculated for each 10-cm portion. The 3 portions are then weighted 4, 2, and 1 progressively with depth to calculate the index 0-30 cm. Figure 12 compares cultivated inter-rows several meters apart under continuous traffic [Index = 2 (20)] and no traffic [Index = 4(73)]. Note: Placements commonly are expressed on a 100 base.

Results

Table 5 gives illustrative data and Table 6 gives the placements in quality classes. A constant-level borehole device (Amoozemeter) is used for the Ksat measurements, which are reference information and are not placed in classes here.

Discussion

- NRCS has several thousand field office employees responsible for implementation of federal programs that may increasingly involve soil quality. These people need simple robust measurements and the associated protocols to reduce the data for communication to the public. Classical procedures may not be appropriate.

- A number of measurements are not discussed. These include several chemical tests as well as aggregate stability. The poster is limited to presentation of in-place physical tests.

- Prior wetting is commonly necessary, particularly for the infiltration and the strength measurements. The soil is deeply wetted the previous day. The range in suction at the ground surface the next day, however, is wide. Therefore, the soil is wetted briefly and the shallow water state controlled by observing the glistening. Tensiometers were tried, but they lack the robustness needed for the people to which the work is directed.

- The usual inundation infiltration method confounds short-term and long-term rates. To illustrate, for Wymore wheat stubble, the calculated overall infiltration rate is 0.019 in hr^{-1} compared to 0.42 in hr^{-1} for the short term and 0.0072 in hr^{-1} for the long term. The short-term infiltration may be the more closely related to quality of the very near soil surface.

- Determination of the morphology index probably would be restricted to soil scientists. The index integrates a lot of information.

- Infiltration rate and morphology index are highly integrative and should tend to change in a parallel fashion if the texture is similar.

Summary

We present several in-place physical tests for the near-surface with accompanying soil quality classes for the results. Except for the morphological index, the tests do not require specialized knowledge and should be executable by NRCS field office staff. The test procedures are directed toward the kind of objective evaluation that may be necessary if soil quality is a consideration in national agricultural programs.

Table 4. Morphology quality classes based on structure, rupture resistance, and macropores.

Class	Feature and Criteria
1	**Structure** - All structures with common or many stress surfaces, massive, platy with firm or stronger horizontal moist rupture resistance, all weak structure except granular, moderate very coarse prismatic, all columnar. **Rupture Resistance** - Very firm and strong if non-clayey. Firm or stronger if clayey (fine, very fine). **Macropores** - Few or none, medium, coarse or very coarse.
2	**Structure** - All structures with few stress surfaces. Weak granular. Moderate very coarse and coarse blocky and coarse and medium prismatic/columnar. Platy with horizontal moist rupture resistance friable. Strong very coarse and coarse blocky or prismatic. **Rupture Resistance** - Firm if non-clayey. Loose if sandy. **Macropores** - Common medium or coarse.
3	**Structure** - No stress surfaces. Moderate medium blocky, and very fine and fine prismatic. Platy with very friable horizontal moist rupture. **Rupture Resistance** - Friable except if coarse loamy. Very friable if sandy. **Macropores** - Common coarse and very coarse.
4	**Structure** - No stress surfaces. Moderate granular. Moderate very fine and fine blocky and very fine prismatic. Strong fine through medium prismatic. **Rupture Resistance** - Friable except if sandy or coarse loamy. Very friable if clayey. **Macropores** - Many medium or coarse.
5	**Structure** - No stress surfaces. Strong granular. Strong very fine through medium blocky and very fine prismatic/columnar. **Rupture Resistance** - Very friable if loamy. Loose if not sandy. **Macropores** - Many coarse and very coarse.

Table 5. Near surface measurements for selected soils[j/].

Soil	Ksat[f/]	Infiltration[g/] Short Term in hr^{-1}	Infiltration[g/] Long Term in hr^{-1}	PR[h/] MPa	Bulk Density[i/] g cc[-1]	Singleton Blade Strength[j/] 0-1 cm kg dm^{-2}	Singleton Blade Strength[j/] 0-2 cm kg dm^{-2}	Singleton Blade Strength[j/] 4-6 cm kg dm^{-2}
[b/]	--	0.51	0.061		1.46	--	1.0	5.6
[c/]	0.12	0.70	0.028	1.3	1.46	1.4	1.6	7.8
[d/]	0.0050	0.42	0.0072	1.3	1.48	0.5	1.6	9.0
[e/]	0.032	1.1	0.041	1.6	1.53	5.2	5.9	7.1

[a/] Ascalon in Petersen, et al. Soil Survey of Washington Co., CO (1986). Sheet 15, NW1/4 Sec 7. T2N R51W. Others, Sec 12, Sheet 27 in Brown, et al, Soil Survey of Lancaster County, NE (1983).
[b/] Ascalon--Aridic Argiustolls fine-loamy, mixed, superactive, mesic. Sandy loam Ap, Wheat stubble, No Till 4 years.
[c/] Judson--Cumulic Hapludolls fine-silty, mixed superactive, mesic. Silty clay loam. Wheat stubble.
[d/] Wymore--Aquertic Argiudolls fine, smectitic, mesic. Silty clay Ap. Eroded. Wheat stubble.
[e/] Wymore--Same classification as proceeding, except near Pachic. Silty clay loam Ap. Permanent grass. Considerable traffic.
[f/] Amoozemeter (constant level borehole device). Median of 3 measurements 10-25 cm. Ordinarily not measured.
[g/] Medians of 5 determinations. Between rows of wheat stubble.
[h/] Penetration Resistance. Median of 9 or 11 determinations on horizontal surface at depth of maximum PR 0-20 cm.
[i/] At depth maximum penetration resistance 0-20 cm.
[j/] Median 5 or 7 measurements. Griffiths, New Zealand Soil Bureau. Sci Rept. 74 (1985).

Table 6. Index placements for data in Table 5.

Measurement	Ascalon Wheat Stubble (No Till)	Judson Wheat Stubble	Wymore Wheat Stubble	Wymore Grass
Infiltration				
Short Term	3	3	4	4
Long Term	2	2	1	2
Pen. Resistance	3	3	3	2
Bulk Density	3	2	2	2
Singleton Strength	2	3	2	3
Morphology Index	3(58)	2(48)	3(43)	3(58)